

Standby Liquid Control System (SLC)

304B Chapter 7.4

Objectives

1. Identify the purposes of the Standby Liquid Control (SLC) System.
2. Recognize the purpose, function and operation of the following major components:
 - a. Storage Tank
 - b. SLC Pumps
 - c. Explosive (Squib) Valves
 - d. Test Tank
 - e. Vessel Injection Line
 - f. Drain Piping
 - g. Neutron Absorbing Solution
3. Summarize the following flowpaths:
 - a. Chemical addition to system
 - b. System flow test
 - c. Injection into the Reactor Pressure Vessel (RPV)

Objectives

4. Identify the conditions that require initiation of the Standby Liquid Control System.
5. Identify why some of the system lines are heat traced.
6. Identify the indications that can be used to verify initiation of the Standby Liquid Control System.
7. Explain the positive reactivity sources considered in the calculation of the minimum average boron concentration that is required to achieve the desired Shutdown Margin of - 0.05% $\Delta K/K$.

Objectives

8. Explain how the Standby Liquid Control (SLC) system interrelates with the following system / components:
 - a. Reactor Pressure Vessel
 - b. Reactor Water Cleanup System (RWCU)
 - c. Reactor Vessel Instrumentation System
 - d. Emergency AC Power
 - e. Demineralized Water System
 - f. Service Air System
 - g. Core Spray System
 - h. Reactor Core Isolation Cooling (RCIC) System

Purposes

- The purpose of the Standby Liquid Control (SLC) System is to inject enough neutron absorbing poison solution into the reactor vessel to shut down the reactor from full power, independent of control rod motion, and to maintain it in a subcritical condition as the plant operators cool the plant down to 70F.

Purpose

- Back-up system shuts down the reactor under the most reactive conditions.
- Shutting down the reactor without control rod insertion in the event of an Anticipated Transient Without Scram (ATWS).
- SLC initiation required in ATWS and LOCA EOPs.

Overview

- The SLC system delivers a borated poison solution to inside the reactor vessel.
- One of two positive displacement pumps will pump the poison.
- Two explosive (squib actuated) valves open to complete the injection path.

Poison Calculation

- Sufficient poison to provide a negative reactivity worth greater than the combined positive reactivity effects of:
 - All control rods fully withdrawn
 - Collapse of all voids
 - Doppler (fuel cooling)
 - Complete Xenon decay
 - Temperature (cooldown to 70F)

Poison Calculation

- Assumed borated volume includes:
 - RHR in shutdown cooling
 - Reactor water level at Level 8
 - $-5\%\Delta K/K$ as an additional shutdown margin

Boron Poison

- The neutron poison is the Boron isotope B-10 contained in a Sodium Pentaborate solution.
- B-10 occurs only as about 20% of natural Boron.
- The effectiveness of the poison can be enhanced by enriching the Sodium Pentaborate to higher concentrations of the B-10 isotope.

Boron Poison

- Sodium Pentaborate powder.
- Readily precipitates out of solution at low temperatures.
- During addition of poison to the storage tank
 - solubility is raised using a large manually operated mixing heater that increases the solution temperature to 150°F.
 - Agitation to promote more uniform mixing is applied by a sparger with six branch lines that vents pressurized Instrument / Service Air to the storage tank.

Storage Tank

- Working capacity of 4,850 gallons based on the old volume requirements prior to the use of enriched Boron-10.
- Means for storage and mixing of the neutron absorber solution.
- Makeup water is supplied by Demineralized Water System.

Storage Tank

- A removable hatch at the top of the tank for chemical addition and sampling.
- A vent and overflow line from the tank is directed to a collection sump.
- Two immersion heaters promote continuous poison solubility.
 - Automatically cycle $80 \pm 10^{\circ}\text{F}$.
 - Powered from Emergency AC Power System.

Heat Trace

- The pipe from the storage tank to the SLC pump suction is heat traced.
- Minimizes precipitated solution.
 - Precipitated poison dilutes the poison available for injection
 - In severe cases may significantly clog the pipe and pump suction reducing the pumping capacity.

SLC Pumps

- Two 100% capacity, triplex piston, positive displacement pumps.
- Each pump has a flow rate of 41.2 gpm against a back pressure of 0-1250 psi.
- Control room and local control switches.
 - Control room switch starts one pump
 - Local switches for testing and do not fire the explosive (squib) actuated valves

Relief Valves & Accumulators

- There are accumulators and relief valves at the discharge of each SLC pump.
- Relief valves open at very high pressure (e.g. 1400 psig) to prevent damage to the discharge pipe or pump.
- Accumulators reduce the vibration and pipe distortion.

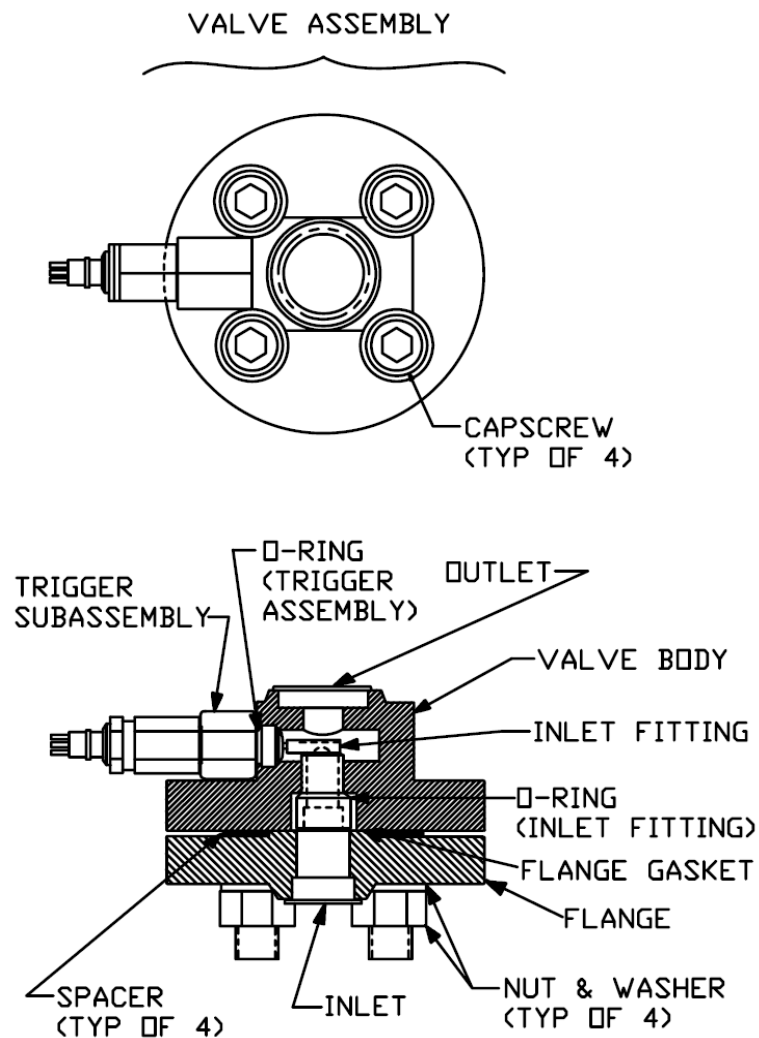
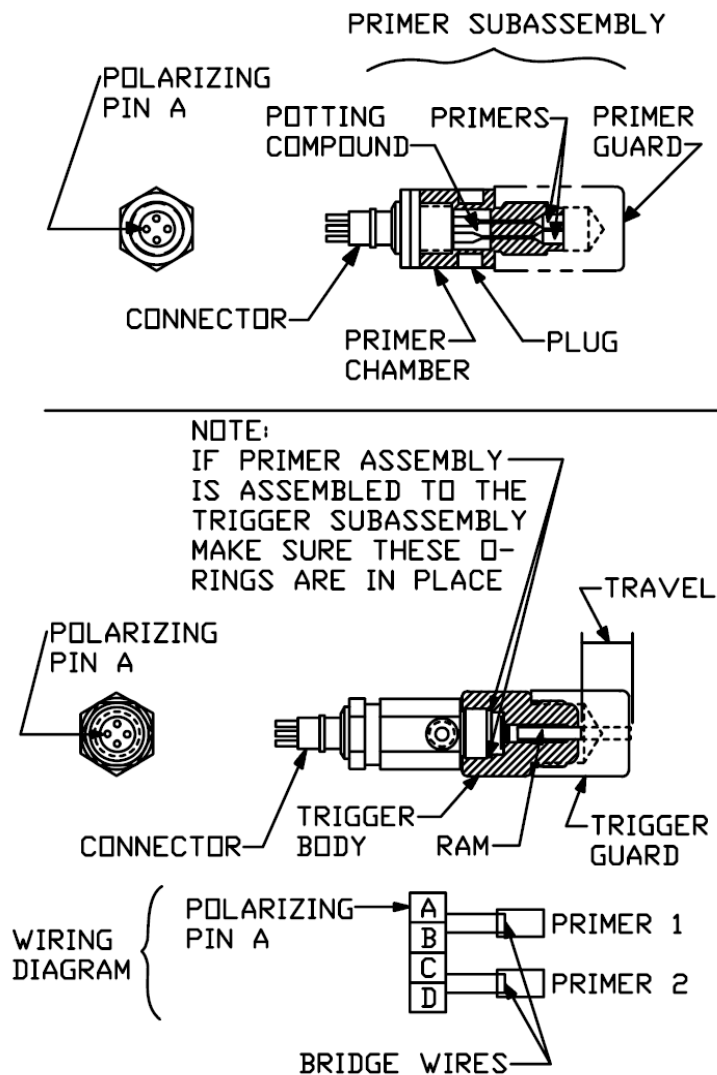
Explosive Valves

- Located between the SLC pumps and the reactor vessel.
- Failure of a single squib actuated explosive valve will not prevent the SLC system from injecting.
- When the system is actuated from the main control room, one pump will start and both explosive valves will open.
- The use of shear plugs prevents Boron from migrating to the reactor vessel.

Explosive Valves

- Squib is a small explosive connected to a remote electronic trigger.
- 2 amperes or greater firing current
- Each explosive valve is double squib actuated
- Ram shears off cap to open valve

Squib Valve (Cross Sectional Views)



Objective 2 & 7.d

Explosive Valves

- Normal standby condition:
 - continuous current of about 1 milliampere through the trigger assembly of each explosive valve.
 - Illuminates an electrical continuity light at the 603 panel
 - Light indicates operability of the squib.

Test Tank

- Testing and flushing
- 210 gallons capacity
- Makeup from demineralized water system.
- Can only be drained to a collection drum via the test tank drain valve.
 - Helps to prevent Boron contamination of treated water.
 - Helps prevent pipe obstructions.

Injection Line

- Dual function within the reactor vessel.
 - provides an injection path for the sodium pentaborate solution
 - Provides tap for vessel instrumentation.
- Two check valves in series, on each side of the drywell

Injection Line

- Normally open manual isolation valve
 - locked open, inside drywell
 - position indication open/close position at 603 panel
- Injection line enters reactor vessel below the core shroud
- Two concentric pipes reduces thermal shock to the reactor vessel during injection

Injection Line

- Inner pipe
 - SLC injection line terminates just below the core plate
 - Used to sense below core plate pressure
- Outer pipe used to sense:
 - Above core plate pressure for core ΔP indication
 - CRD System vessel pressure
 - core spray line break detection.

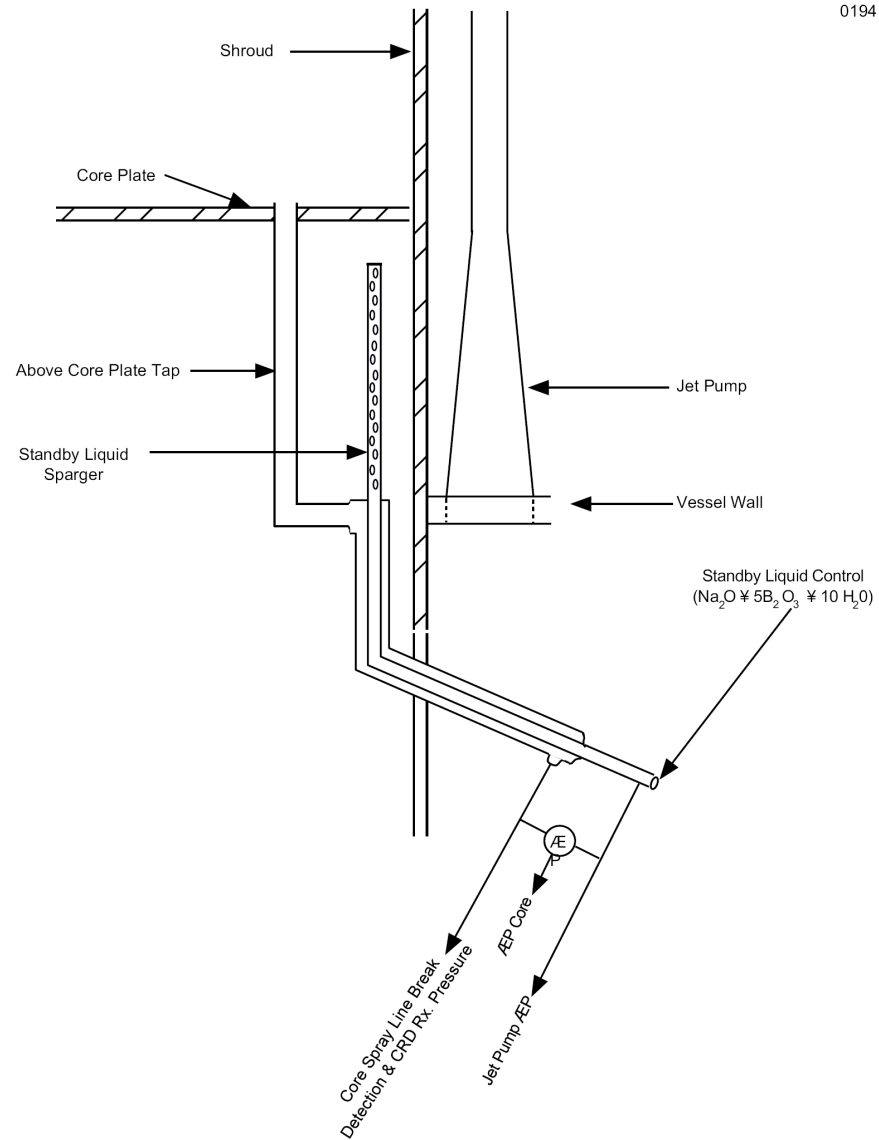


Figure 7.4-3 Standby Liquid Control Sparger Layout

Objective 2

Drain Piping

- Drain piping from
 - pump suction cross connect line
 - pump base plate
 - pump discharge cross connect pipe
 - test tank
- Piped to a 55 gallon drum.
- Radwaste system does not have to process borated waste.
- Borate precipitation will not obstruct drains

Boron Poison

- Poison mixture is a white powder made primarily of Borax & Boric Acid.
 - Solution of sodium pentaborate decahydrate
- The B-10 is a very effective neutron poison. B-11 is not.
 - Poison mix has been enriched to more than 85% of B-10.
- The poison has a shelf life of 40 years.

Boron Poison

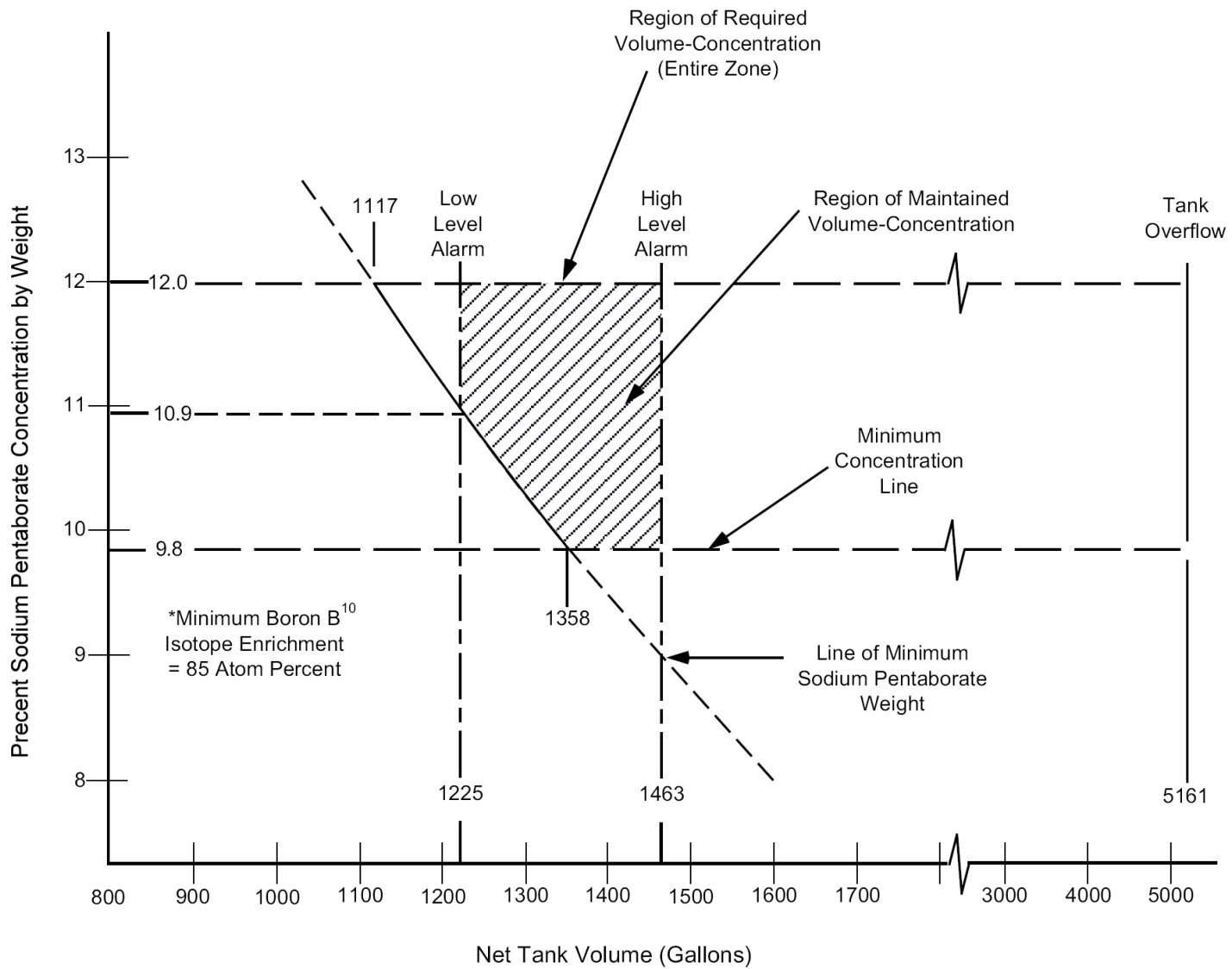
- ATWS rule 10CFR50.62 required improved shutdown capability.
- Many utilities decided to enrich the Boron poison instead of injecting with two SLC pumps.
- Enriched poison reduced calculated core damage frequency and provided twice the shutdown capability required by the ATWS rule.

Boron Poison Hazards

- Very toxic affecting the central nervous system.
 - Poisoning causes:
 - Reduced blood circulation
 - Persistent vomiting and Diarrhea.
- Severe poisoning causes low body temperature which may result in a coma or death.
- A severe rash may cover the entire body.

Normal Line-up

- SLC system normal line up in Figure 7.4-1.
- The SLC storage tank is maintained between the high and low level alarm points.
- The required amount of poison solution and poison concentrations maintained per TS.
- The storage tank and piping are maintained at their required temperatures to prevent the solution from precipitating.



Objective 2

Figure 7.4-4 Sodium Pentaborate Solution Concentration vs. Net Tank

Injection Mode

- Manual actuation only
- Select switch to the “Start Sys A” or “Start Sys B” positions
- One SLC pump running with both explosive valves open

Injection Mode

- Positive indications of system injection include the following:
 1. Pump on light for the system started
 2. Loss of continuity light and alarm
 3. Pump discharge pressure
 4. Storage tank level decreasing
 5. Reactor power decreasing

Test Tank & Flow Testing

- Flow rate testing locally at the pumps.
- Local pump start and stop switches will not fire the squibs on the explosive valves.
- Testing pumps water from SLC pump to a line connected to the pump vent.
- Pumped water is sent to a collecting drum where the water is measured.

Actuation testing

- Actuates one of the explosive valve squibs.
- Water from test tank pumped into reactor.
- Flow rate verified.
- Requires replacement of fired explosive valve.

System Interfaces

- Reactor vessel
 - Injection under core plate
 - Pipe within pipe

System Interfaces

- Reactor water cleanup
 - RWCU system isolates
 - Minimizes borated volume
 - Prevents demineralizers from lowering poison concentration

Review

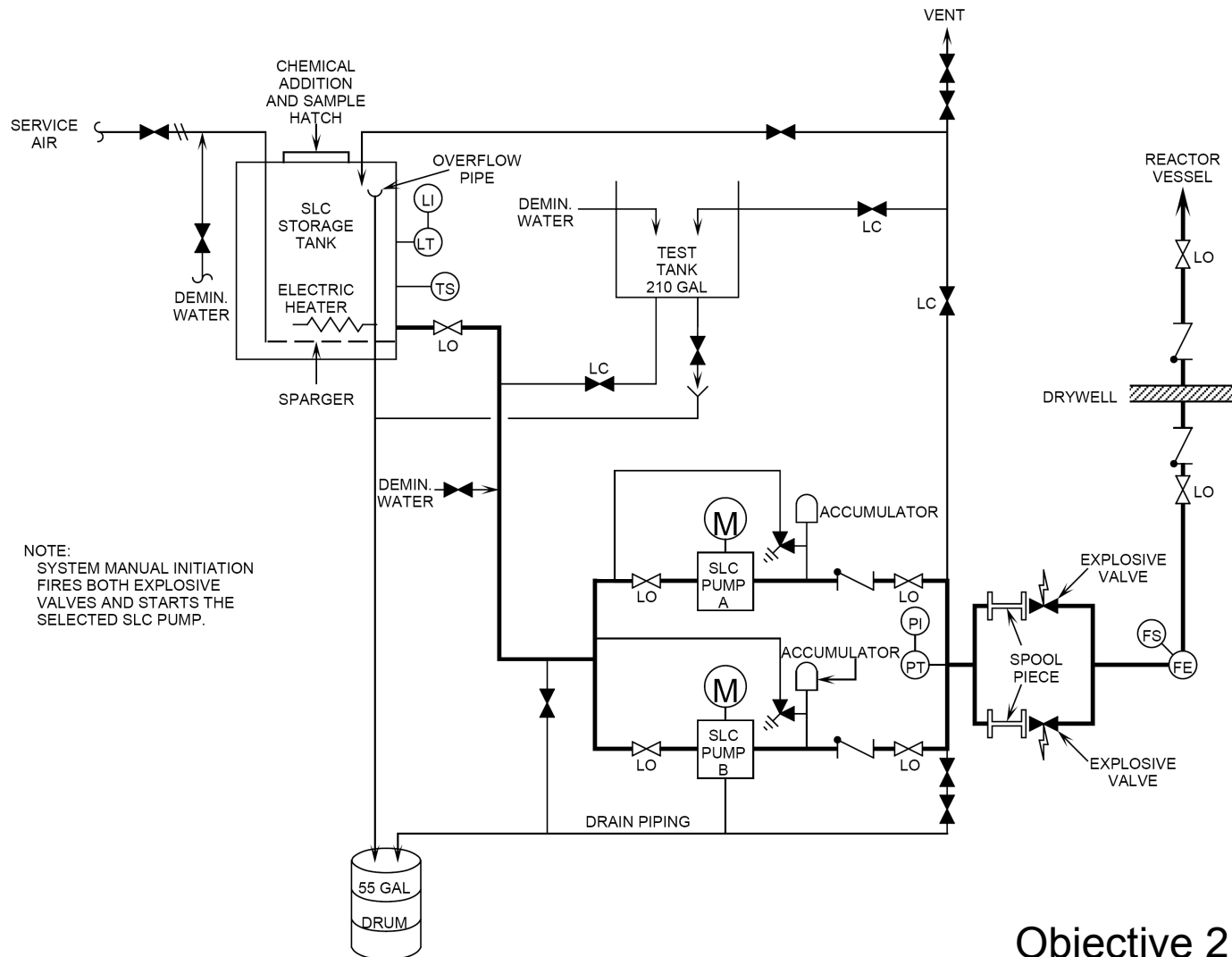


Figure 7.4-1 Standby Liquid Control System

Objective 2

Objectives

1. Identify the system's purposes.
2. Explain how the system accomplishes its purposes.
3. Explain why some of the system lines are heat traced.
4. Identify the conditions that require initiation of the Standby Liquid Control System.
5. Identify the indications that can be used to verify initiation of the Standby Liquid Control System.

Objectives

6. Describe the positive reactivity sources considered in the calculation of the minimum average boron concentration that is required to achieve the desired Shutdown Margin of - 0.05% delta K/K.
7. Explain the purpose and operation of the major system components:
 - a. Storage tank
 - b. Test tank
 - c. Pumps
 - d. Explosive valves
 - e. Accumulators
 - f. Relief Valves

Are there any questions?